PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A
MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Afghan Seismotectonics

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Afghan seismotectonics

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A tectonic model for the regions of Afghanistan based on global and continental tectonics and known fault systems is presented and discussed. It is postulated that an Iran–Afghan crustal block is acting as a buffer block between the stable Asian mass on the north, the Indian–Australian crustal plate on the east and southeast, and the Arabian Peninsula block on the southwest. A regional seismicity map based on instrumental data detected during the time period of 1893 to 1969 for Afghanistan is made. By overlapping the 1893 to 1969 regional seismicity map on the regional fault systems a seismo-tectonic map for the regions of Afghanistan is constructed.

Regional tectonics

The analysis of global and continental tectonics can set the stage for discussing the localized tectonic patterns in Afghanistan. It seems clear that the movement of the Indian–Australian crustal plate which is thrusting N–NE along the eastern regions of Afghanistan will be the dominant factor governing tectonic processes and promoting seismic activity in the eastern portion of the country. The rotation of the Arabian Peninsula away from the Red Sea will be the dominant factor affecting the tectonics of Iran proper and possibly the southwestern portions of Afghanistan. The coupling of these two continental movements and their interaction with the stable Asian mass in the north establishes the framework within which all localized tectonic mechanisms of Afghanistan must be set.

The approach to discussing the local tectonic patterns will be to present first the available information on the visible fault systems existing in the country. Mapped fault lines which appear on the surface of the Earth along with data about their sense of movement are the keys which reveal the existence and nature of localized tectonic processes.

Fault systems

The fault systems which traverse Afghanistan have been identified through various geological and aerial photographic surveys. For this discussion two sources of information are relevant. The first is the recent 1969 geological map of Afghanistan (figure 1) and the second is the map of active faults prepared by H. W. Wellman (figure 2).

Wellman's investigations were performed during 1964 and were based almost exclusively on the use of air photo mosaics to identify the active transcurrent fault systems for the regions of Pakistan, Afghanistan and Iran. The overall appearance of the fault patterns revealed by Wellman agree reasonably well with the geological map but in detail they do differ. We used Wellman's data and augmented it with any major fault system shown on the geological map and not detected by Wellman.

Wellman recognized the Chaman, the Herat, the Shahrud, and Zagros as the major active faults. Figure 3 shows a rough sketch of the relative sites of these faults. Wellman also observed that the Herat and the Zagros are right lateral faults, whereas the Chaman and the Shahrud are left lateral faults. Recent ground displacement associated with earthquakes are in agreement with Wellman's observation.

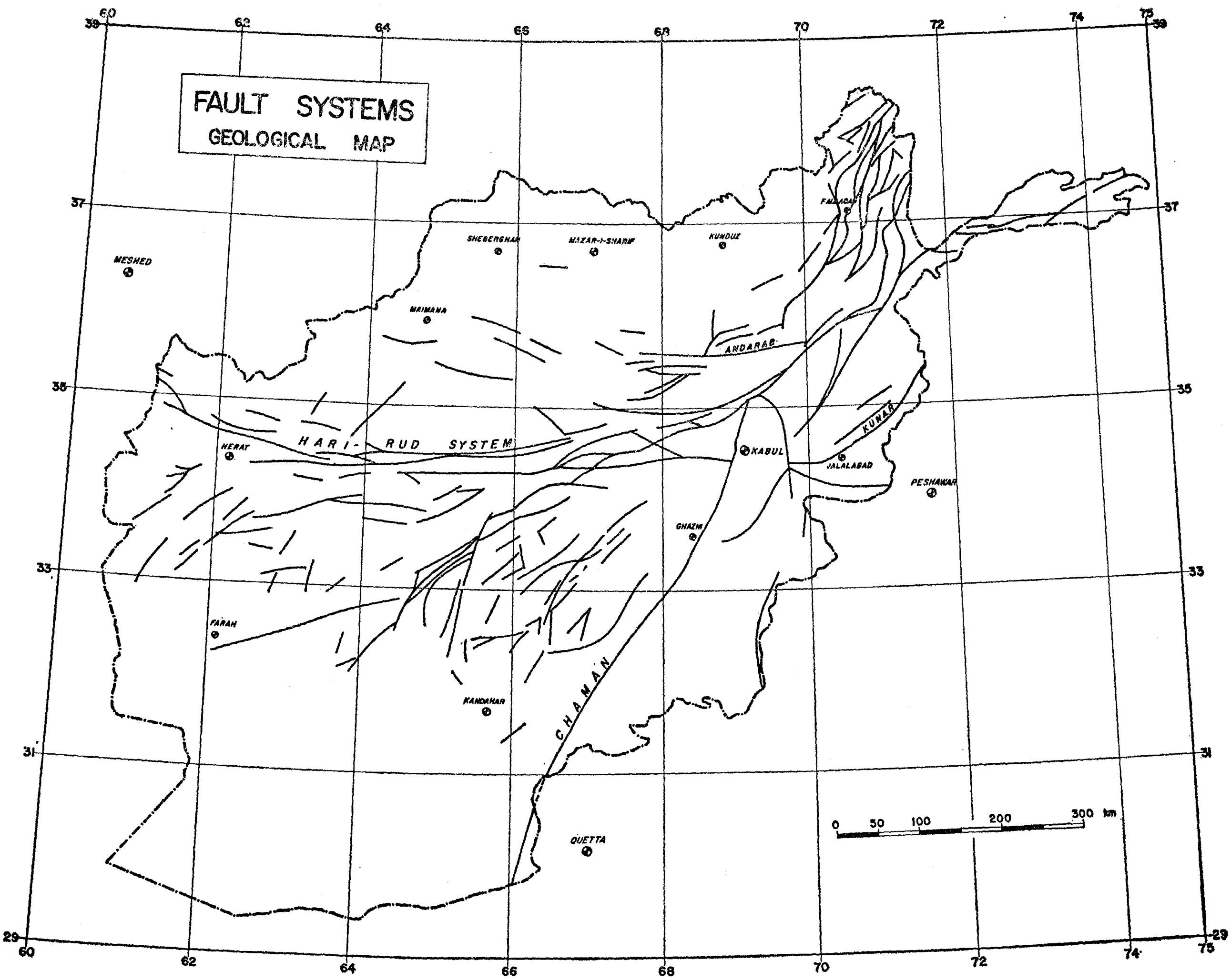

FIGURE 1. Fault systems in Afghanistan from the geological map.

Proposed tectonic patterns

A tectonic model was proposed for the regions of Afghanistan by Wellman in the same paper in which he presented the fault systems. From the broad survey covering Pakistan, Afghanistan and Iran, Wellman established that the Dasht-i-Lut depression in eastern Iran was behaving as a contraction centre, towards which all regional crustal blocks west of the Chaman fault were moving. This was deduced by observing that the major transcurrent faults (Chaman excepted) had the appearance of spiralling outwards from the Lut centre.

Wellman's postulation about the existence of a contraction centre as the hub of the regional tectonic patterns is an interesting model. The question which arises of course is, does this model fit into the global and continental tectonic patterns?. Although based primarily on conjecture, the following continental pattern will be submitted as a possible tectonic mechanism to complement Wellman's regional model.

From Wellman's investigation it appears that it may be possible to define a subcontinent crustal block containing the regions of Iran, Afghanistan and Pakistan, and delineated by transcurrent fault lines. The block being postulated is demarcated by the Chaman and Gardez

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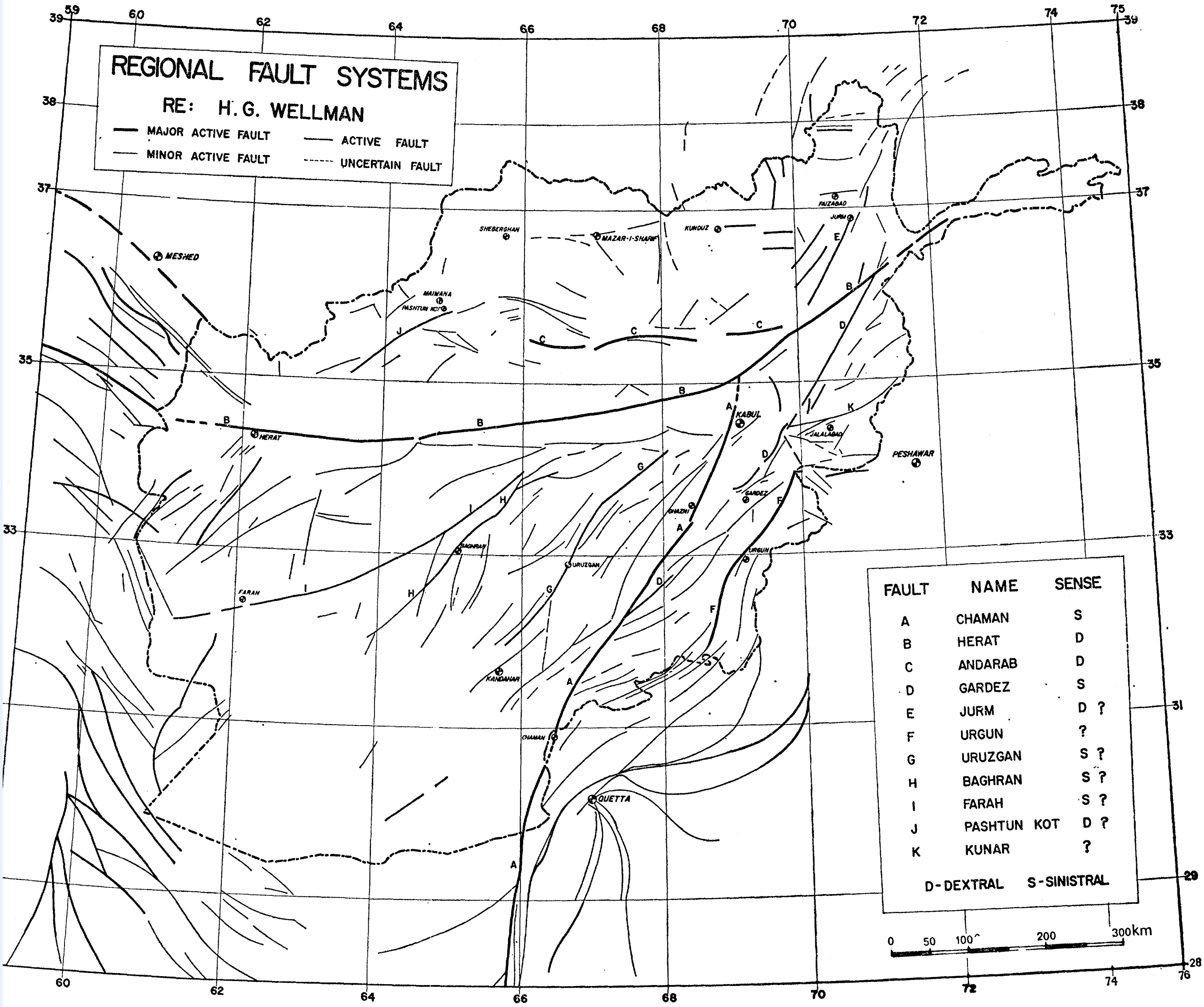

FIGURE 2. Regional fault systems mapped by H. W. Wellman.

sinistral faults for the eastern edge, by the Herat dextral fault as the east section of the northern edge, by Shahrud sinistral fault running the strike of the Alborz mountain range and around the base of the Caspian Sea as the west section of the northern edge, and by the Zagros mountain range. The latter fault forms the southwestern edge of the block. According to Wellman's regional map there are numerous secondary faults which strike west from the Chaman fault and may serve as suitable extensions to complete the boundaries of the block. The block thus envisaged has the shape approximating a thick irregular-shaped crescent, with concave face north and convex face south. A very similar subcontinental block has been used by W. J. Morgan for the regions of Iran, Afghanistan and the extreme western section of Pakistan.

If the crescent-shaped block described above is realistic, then the block is essentially acting as a buffer block between the stable Asian mass on the north and the two northward movements of the Indian–Australian crustal plate on the southeast, and the Arabian Peninsula block on the southwest. In such a position it is very clear that this subcontinent crustal plate will be in a state of compression and in this regard Wellman's postulation of a contraction centre fits well.

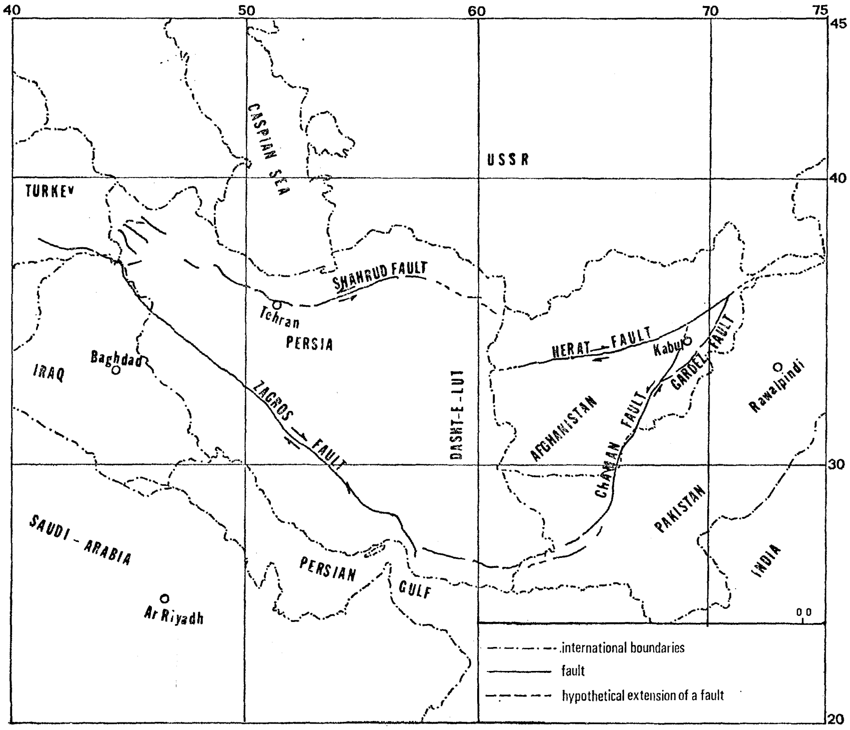

FIGURE 3. Rough sketch showing Chaman, Herat, Shahrud, and Zagros faults.

The exact manner by which the surrounding continental crustal plates are compressing this, essentially, Iran–Afghan block, is of course not a simple problem. From the sense of displacement of the transcurrent fault lines defining the edge of the block, it can be inferred that the compression is forcing the tips of the crescent inward toward each other. To support this point a possible physical mechanism will be proposed. For this purpose consider the crescent tip situated in Afghanistan and defined by the junction of the Herat and Gardez faults. To the east of the Gardez fault crustal material is moving roughly in a N–NE direction in sympathy with the spreading of the Carlsberg ridge. As this material is thrust into the corner formed by the Hindu Kush and Himalayan ranges a severe compression pocket is created. Because the Himalayan range is immensely more massive than the Hindu Kush the relief of this compression pocket will be one of movement parallel to the strike of the Himalayas or perpendicular to the Hindu Kush strike, and hence, the mechanism for forcing the crescent tip westward. It should also be stated that thrusting perpendicular to the Hindu Kush will promote considerable buckling and uplifting and the transcurrent faults should exhibit considerable dip-slip components. It is interesting to note that in Ritsema's fault plane solutions for earthquakes in the Hindu Kush, he found that the direction of maximum stress for shallow earthquakes was indeed perpendicular to the strike of the Hindu Kush.

The postulation of the existence of an Iran–Afghan crustal block in the shape of a crescent and being compressed by the surrounding continental plates is a plausible tectonic model for the information available. The argument for the tips of the crescent being forced toward one another is also reasonable and is in keeping with Wellman's contraction centre hypothesis and Ritsema's calculation. The fact that the observed seismic activity is very much confined to the edges of this block and particularly the regions surrounding the tips of the crescent, adds further credence to

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the model. The lack of notable seismic activity in the centre of the block around the Sistan and Dashti-Lut regions would seem to be an expected result. It may well be that the plate has some rotation and this would complicate the situation considerably. For the present in view of the existing data it is felt that the proposed tectonic mechanisms of an Iran–Afghan crustal block is a reasonable model.

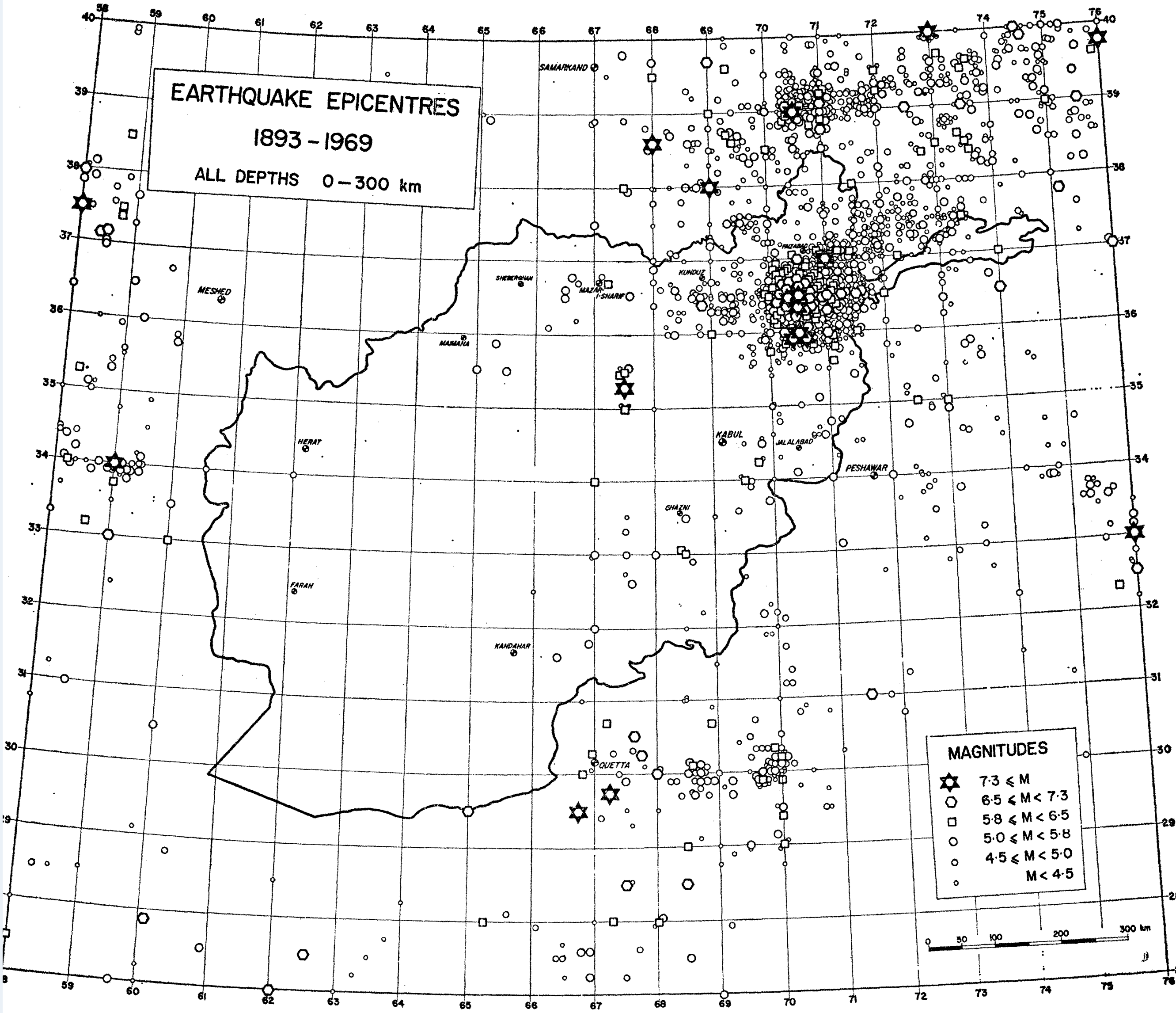

FIGURE 4. Seismicity map showing all earthquakes from 1893 to 1969.

Seismo-tectonic analysis

For the present study it was deemed essential that a seismo-tectonic analysis in the form of a map should be presented. An analysis of this type would represent in one map a summary of most of the regional tectonic systems as presently known for Afghanistan based on instrumental data. Figure 4 shows a plot of all earthquakes detected instrumentally during the time period of 1893 to 1969.

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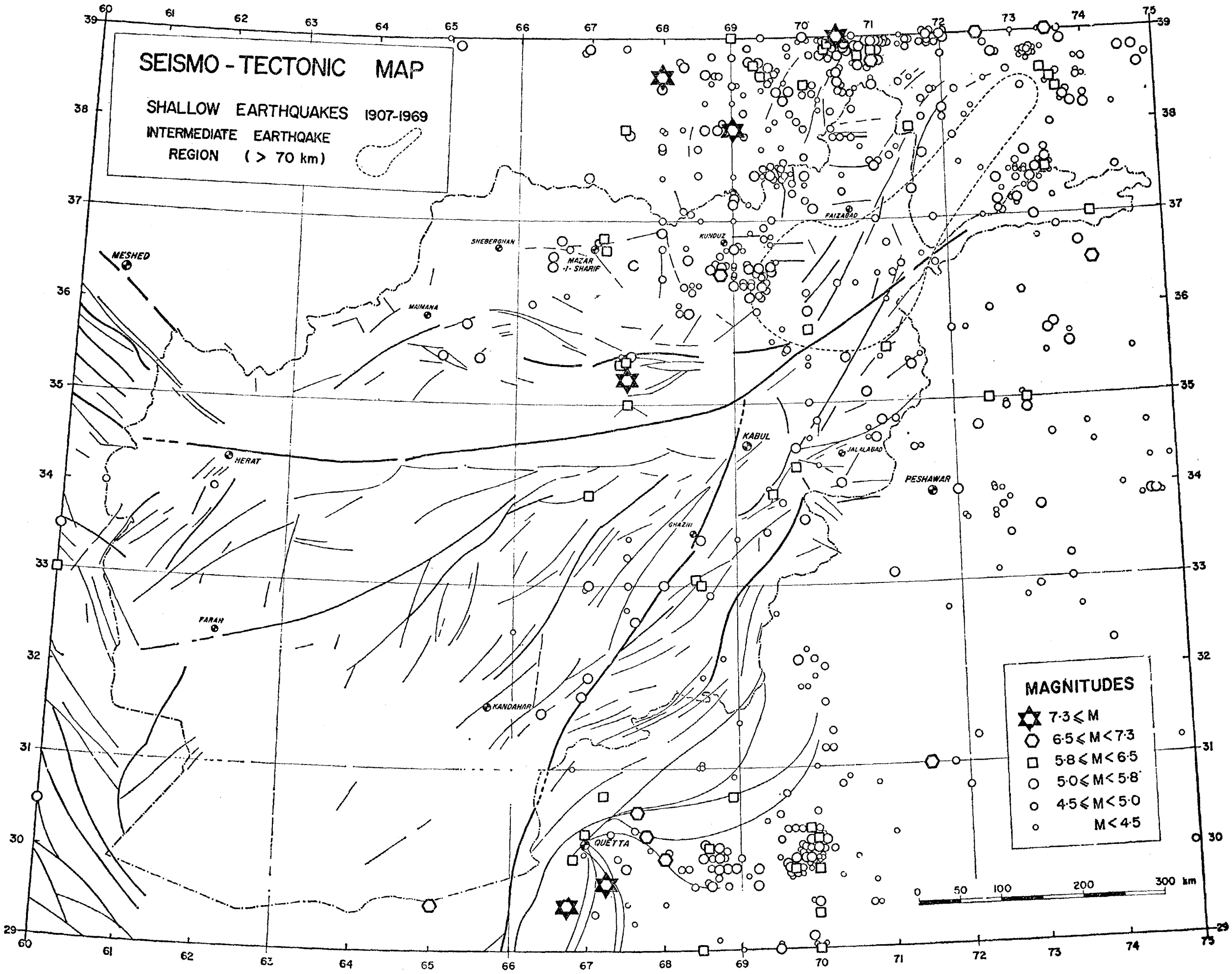

FIGURE 5. Seismo-tectonic map of Afghanistan.

By overlapping the 1893 to 1969 regional seismicity map on the regional fault system map a seismo-tectonic map for the regions of Afghanistan is constructed (figure 5). Because the fault systems were not known for the extremities of the broad region, and because the purpose of the map is primarily directed towards the needs of Afghanistan, the smaller zone was chosen. Secondly, as shown in this figure, the intense pocket of earthquake epicentres associated with the intermediate depth earthquakes has been deleted and replaced with simply a boundary denoting the region wherein these earthquakes occur. All earthquakes which appear in the figure are shallow events (< 70 km). The reason for only considering shallow earthquakes in the seismo-tectonic analysis is that the fault lines which appear on the surface are very unlikely to be associated with the deep or intermediate depth earthquake events.

The information presented in figure 5 is extensive and many important features are depicted. Certainly one of the most interesting developments in view of the discussion relating to the movement of the Indian–Australian crustal plate is the seismic activity along the Chaman fault. Although the activity is shifted to the east in the Quetta region, it is evident that the Chaman fault is active within Afghanistan as far north as Ghazni. Related to this observation is the obvious seismic activity which is coincident with the Gardez fault system throughout its entire length. The lack of any significant events to the immediate west of the system gives strong support to the statement that the Gardez fault system forms part of the transcurrent fault which demarcates the northwestern edge of the Indian–Australian crustal plate. The further observation that the northern end of the Gardez fault system intersects the Herat fault at nearly the precise location of the > 200 km depth earthquake zone, is indeed further evidence to support the statement. If there are convection cells within the mantle which are dragging the Indian–Australian crustal plate N–NE, and if the material in these cells is down-thrusting in the Hindu Kush centre, then the Gardez fault system along with its observed seismic activity and its observed intersection with the Herat fault above the point of intermediate depth earthquakes, is an acceptable physical manifestation of this postulated driving mechanism.

The second notable feature is the lack of any epicentres near to the major transcountry Herat fault throughout most of its length. In view of the significance attached to this fault as presented in the discussion of the regional tectonics the lack of associated seismic activity is surprising. The evidence that Herat City was heavily damaged by an earthquake in A.D. 848 provides some testimony that the fault is active. On the other hand, it is unlikely that any strong earthquake has originated from this tectonic system in the last few decades.

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